AT THE ENTERPRISES AND INSTITUTES

UDC 666.3-413

WET EXPANSION OF DOUBLE-FIRED CERAMIC-TILE ENGOBES

D. F. Zvezdin[1] and A. V. Kir'yanov[1]

Translated from *Steklo i Keramika*, No. 9, pp. 41 – 42, September, 2006.

The effect of engobe on wet expansion of double-fired tile was demonstrated. Engobe with insignificant wet expansion, which improves the performance properties of the tiles, was obtained.

Use of tiles in premises with high humidity requires special attention to such a defect as delayed crazing, i.e., formation of hairline cracks. This defect arises if the stresses caused by expansion of the base (ceramic base and/or engobe) is higher than the tensile strength of the glaze coating the tile. We know that the base most frequently expands under the effect of water that goes inside the tile from bricklaying mortar (adhesive) and from the atmosphere through masonry joints. The water reacts with the glass phase present, which increases in volume and causes wet expansion as a result. The mechanism of formation of delayed crazing of ceramic tile is shown in Fig. 1, and methods of determining it are given in Fig. 2.

The alkali metal oxides in the tile paste cause the formation of glass phase which cannot produce a sufficient amount of crystalline phases during high-speed firing. The effect of the individual components of the ceramic paste on wet expansion of double-fired porous ceramic material was examined previously [1]. However, since ceramic tile has a multilayer structure, it is also necessary to verify the effect of other structural elements on the appearance of delayed crazing.

We found during industrial tests that engobe – the underglaze layer applied on the intermediate product for whitening and as a damping-process layer (concealment of surface defects and irregularities and prevention of the appearance of gases and salts from the ceramic base in the glaze layer) – is also subject to wet expansion. To reveal the effect of engobes on the appearance of delayed crazing of double-fired ceramic tile, we measured their wet expansion.

The samples for the tests were prepared and fired slightly differently than for determination of the wet expansion of unglazed samples after the first firing to most accurately simulate the industrial conditions of application (layer thickness of approximately 0.1 mm) and firing of engobes. Tiles (55 × 110 mm) no more than 1.5 – 2.0 mm thick were molded from molding powder with a 5 – 6% moisture content at a

[1] Lira Keramika Ltd., Moscow, Russia.

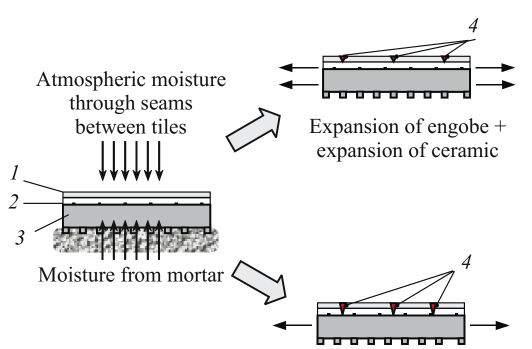

Fig. 1. Mechanism of formation of delayed crazing: *1*) glaze; *2*) engobe; *3*) ceramic; *4*) hairline cracks.

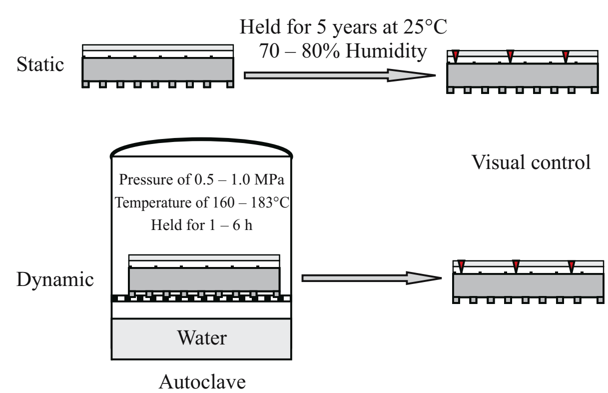

Fig. 2. Methods of determining delayed crazing of double-fired ceramic tile.

TABLE 1

Engobe	Mass content, %									
	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	TiO_2	ZrO_2
No. 19	7.9 – 9.9	2.5 – 4.5	0.5 – 2.5	< 0.2	1.6 – 3.6	0 – 0.5	1.2 – 3.2	69.0 – 73.0	< 0.2	8.5 – 11.5
No. 35	12.0 – 14.0	1.2 – 3.2	3.5 – 6.0	< 0.2	0 – 0.6	< 0.2	4.0 – 7.0	62.0 – 68.0	< 0.3	6.2 – 10.2

TABLE 2

Engobe	Firing temperature, °C	Water absorption, %	Wet expansion, %
No. 35	1060	5.1	0.023
No. 19	1060	11.9	0.084
	1100	2.1	0.015

pressure of 40 MPa. After drying, the tiles (engobes) were fired on a thin ceramic support at a second firing temperature of 1060°C. As a result, samples with a degree of compaction close to the degree in industrial use of engobes.

The wet expansion tests were performed in an autoclave under pressure of 1 MPa for 6 h with slow (natural) cooling. The wet expansion was calculated from the results of 20 measurements for each series of samples. A micrometer with an accuracy limit of ± 1 μm was used to measure the dimensions of the samples.

The chemical compositions of two engobes, one of which (No. 19) caused delayed crazing in the double-fired tile, are reported in Table 1.

On the whole, the engobes compared had similar compositions. Nevertheless, engobe No. 19 had very high wet expansion – approximately 0.084%, while the expansion of engobe No. 35 was only 0.023% (Table 2). Both engobes contained an almost identical amount of alkaline oxides. As a consequence, these engobes should have similar wet expansion.

In addition, engobe No. 19 had high water absorption, 11.9% (the water absorption of engobe No. 35 was 5.1%). In view of the low temperature and short firing cycle (38 min), which was insufficient for crystallization of the glass phase (its content should be significant according to the data from the chemical analysis), a hypothesis was advanced concerning the effect of the open porosity on the development of wet expansion of the engobe, since high open porosity causes greater penetration of moisture in the engobe and increases its wet expansion.

To reduce the open porosity, a series of samples was prepared with engobe No. 19 and fired at 1100°C (with the cycle unchanged). As the data in Table 2 show, water absorption (open porosity) decreased to 2%. Wet expansion then decreased significantly (to 0.015%).

When it is impossible to convert a large amount of glass phase to the crystalline state, wet expansion can thus be reduced by decreasing (to less than 5%) the open porosity of the engobe.

REFERENCES

1. D. F. Zvezdin and A. V. Kir'yanov, "Wet expansion of double-fired ceramic tile," *Steklo Keram.*, No. 1, 19 – 20 (2006).